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Docket Number 50-346

License Number NPF-3

Serial Number 1-1272

April 30, 2002

Mr. J. E. Dyer, Administrator
United States Nuclear Regulatory Commission
Region III
801 Warrenville Road
Lisle, IL 60532-4351

Subject: Responses to NRC Questions on the Preliminary Probable Cause Summary
Report dated March 22, 2002

Ladies and Gentlemen:

A preliminary Probable Cause Summary Report regarding the Reactor Pressure Vessel (RPV) head degradation at the Davis-Besse Nuclear Power Station, Unit 1 (DBNPS) was provided to the Nuclear Regulatory Commission (NRC) Augmented Inspection Team on March 22, 2002. During the review of this preliminary report, the NRC staff developed 32 questions. The purpose of this letter is to provide the NRC staff with the enclosed responses to those 32 questions.

The Root Cause Analysis Report for the RPV head degradation was submitted to the NRC on April 18, 2002, by letter Serial Number 1-1270. Information that addresses many of the questions provided by the NRC staff is covered in that report. For these questions, a reference to the appropriate section of the report is provided in the enclosure to this letter.

In some cases, the report does not contain information to fully address the NRC staff questions. For these questions, the enclosure to this letter provides supplemental information and clarification.

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If you have any questions or require additional information, please contact Mr. David H. Lockwood, Manager – Regulatory Affairs, at (419) 321-8450.

Very truly yours,

A handwritten signature in black ink, appearing to read "J.W. Byrdahl". The signature is written in a cursive style with a large, prominent initial "J" and "W".

Enclosure and Attachment

cc: USNRC Document Control Desk
S.P Sands, DB-1 NRC/NRR Project Manager
D.V. Pickett, DB-1 NRC/NRR Backup Project Manager
C.S. Thomas, DB-1 Senior Resident Inspector
Utility Radiological Safety Board

Davis-Besse Nuclear Power Station
Responses to NRC Questions on the Preliminary Probable Cause Summary Report

1. Question: Is there a role of the extent of the interference fits of nozzles 2 and 3 at the operating conditions (as described by finite element gap analysis by SIA) in promoting the initiation of the degradation?

Response: A Finite Element Analysis of the gap between the Control Rod Drive (CRD) nozzles and the Reactor Pressure Vessel (RPV) head was provided as part of the October 17, 2001 submittal letter (Serial Number 2735). This analysis indicates a negligible interference fit between nozzles 1, 2, 3, and 4 and the RPV head nozzle bore after loading is applied. The Davis-Besse nozzle interference fits are consistent with other plants that had leaking nozzles but have not reported similar degradation. Therefore, there is no clear role of the interference fits in initiating the degradation.

2. Question: Why was there degradation behind nozzles 2 and 3 at Davis-Besse and not behind similarly cracked nozzles at other facilities, e.g., Oconee? Did the characteristics of the interference fit and other design characteristics of nozzles 2 and 3 play a role?

Response: It is likely that the more severe degradation resulted from some combination of longer cracks, longer time of leakage, and boric acid being left on the RPV head. See Root Cause Analysis Report (RCAR) Section 3.2.1 (page 11), Section 3.2.2 (page 17), Section 3.2.4 (pages 20-26), and Section 3.6 (pages 49-51). Interference fits are discussed in the response to question 1.

3. Question: What evidence is there to indicate that the leakage from nozzle #3 began 2 to 4 operating cycles ago?

Response: The evidence that leakage began 2-4 operating cycles ago is best explained by reference to the timeline depicted on Figure 26, Section 3.2.1 (page 14) and discussed in Section 3.3 (pages 26-37) of the RCAR. In summary, this conclusion is based upon a combination of factors, including corrosion rates, the timing of changes in the characteristics of the boric acid on top of the reactor vessel head, and the timing of increases in containment Radiation Monitor filter replacements and Containment Air Cooler (CACs) cleanings.

4. Question: Did you determine if the nozzle heat of material played a significant role in increasing the likelihood of cracking, given experience with this heat at other plants?

Response: RCAR Section 3.2.1 (Pages 12 and 13) addresses issues pertaining to the nozzle heat of material. These sections indicate that CRD nozzle heat number M3935 appears to be more susceptible to primary water stress corrosion cracking (PWSCC) than other heat numbers.

5. Question: With the low leakage rates from cracked nozzles identified at other plants (e.g., 1 gallon per year at Oconee Unit 3), what are the estimated leakage rates from nozzles 2 and 3?

Response: See RCAR Section 3.2.2 (pages 17 and 18).

6. Question: How was sufficient moisture retained on the head or in the cavity (once formed) at the operating conditions of 500°F to 600°F to allow the degradation to occur?

Response: RCAR Section 3.2.4 (pages 20-26) provides a discussion on the build-up of moisture in the cavity.

7. Question: How do you account for the black particles (presumably magnetite - created either in an oxygen free environment, or at temps greater than about 450°F) found in the containment air coolers (according to the SwRI analysis) and the reddish-brown coloration (presumably hematite - formed only at lower temperatures such as than about 350°F and requiring excess oxygen) of the boric acid wash products found exiting from the head surface in recent years?

Response: The Southwest Research Institute analysis is of particles found on the Radiation Monitor filter elements and not the CACs. However, there was at least one report of red coloration on a face of the CACs. There have been several environments for formation of iron oxides that could contribute to particles on the Radiation Monitors. Refer to RCAR Section 3.2.4 (pages 20-26), 3.3.4 (pages 31 and 32), and 3.3.5 (pages 33-37).

8. Question: How do you reconcile/correlate the corrosion rates presented in the EPRI Boric Acid Guidebook, detailing data developed from short term and dimensionally small experiments, with the longer term and larger scale of the Davis-Besse event. For example, the guidebook describes a steam jet experiment with a jet 0.5 in. from a steel plate producing corrosion rates of 6.4 to 11.1 in./yr. At a jet-to-plate distance of 2 in., the rates decreased to 0.4 to 3.9 in./yr. How would these rates project to the much greater distances found in the nozzle 3 cavity?

Response: RCAR Section 3.2.4 (pages 20-26) discusses the postulated corrosion rates on the head vs. the EPRI Boric Acid Corrosion Guidebook, Revision 1.

9. Question: Discuss, at least qualitatively, why the cavity could NOT have been formed prior to the through-wall penetration of the axial crack(s), by a low-intermediate temperature wastage mechanism involving concentrated boric acid solutions produced by accumulations originating from CRDM flange leakage. For example, during some of the extended outages in the early going (1970's), wastage could have initiated and developed around the nozzle penetration counterbore. Each time the reactor shut down, additional CRDM flange leakage could have re-wetted these enclaves, and wastage could have proceeded during the outage, until the enclaves dried out again as the plant returned to operation. If head temperatures during the outage periods were less than 200°F for a reasonable period of time, this wastage could have been quite rampant.

Response: The model suggested by the NRC would apply if the plant spent long periods of time with head temperatures in the range of 180-225°F. Although comprehensive reconstitution of early plant operation has not been performed, it is believed that the early long periods of lay-up were at much lower temperatures. The EPRI Boric Acid Corrosion Guidebook, Revision 1, shows lower corrosion rates for these lower temperature conditions. The corrosion depth can be estimated using the model in Example B-1 of the Boric Acid Corrosion Guidebook, Revision 1.

If a significant corrosive attack mechanism occurred under low temperature conditions, then it would have been expected to occur on other nozzles that were similarly wetted by flange leakage over periods of early operation. Visual inspections conducted to date have not revealed any significant signs of corrosive attack on the surface at other areas.

10. Question: It is clear that corrosion rates of stainless steel (i.e., as in cladding) in quiescent, concentrated boric acid solutions is nearly zero. If steam jet cutting/erosion is cited as the dominant contributing factor in the low-alloy steel wastage, support with corrosion data the observation that the cladding was completely untouched by the borated steam jet.

Response: While not a dominant factor in the large corrosion cavity at nozzle 3, steam cutting may have played a role in initially opening up the annulus. Once the annular gap opens up, steam cutting is not believed to have played a dominant role. A resistant surface such as stainless steel cladding would not be impacted. Refer to RCAR Section 3.2.4. (pages 20-26) for a discussion regarding the formation of the nozzle 3 cavity.

11. Question: What was the maximum linear extent (not rate) of the wastage observed for the EPRI and CE tests reported in the EPRI Boric Acid Guidebook? Describe dimensions along the axis of the tube, radially from the tube, and circumferentially around the tube.

Response: Davis-Besse contacted EPRI for this information. The maximum depths of penetration in the EPRI and CE annulus tests were 0.32 inches and 0.13 inches respectively.

12. Question: What basis is there for assuming that the maximum rate of wastage at Davis-Besse averaged 2 inches per year and was limited to 4 inches per year?

Response: RCAR Section 3.2.4 (pages 20 and 21) discusses the estimated corrosion rates.

13. Question: At what point in the wastage process is the maximum rate believed to have occurred, and why?

Response: The maximum sustained rate is believed to have occurred late in the process when the leakage rate was high and the wetted area was well oxygenated. See RCAR Section 3.2.4 (page 24 and 25).

14. Question: Is the wastage process assumed to be purely corrosion, or is corrosion assisted erosion considered to be involved during some or all of the cavity excavation?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

15. Question: How did the corrosion of the head initiate? Did it initiate from the top down, from the bottom up, or both? What is the rate of degradation? What experimental evidence do you have confirming your theory?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

16. Question: If the corrosion occurred from the bottom up, where did the oxygen, which is necessary for the corrosion to occur, come from? If the oxygen came from the interference fit between the nozzle and the head, discuss the permeability of the boric acid layer on top of the head to oxygen. What experimental data do you have confirming your theory? Could this degradation have occurred in the absence of oxygen?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

17. Question: What corrosion rate would be expected given the amount of oxygen that could have passed through the boron layer at the top and through the interference fit?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

18. Question: Discuss how you can conclude whether discoloration of the boric acid deposits on the top of the head are due to corrosion of the base metal of the head versus corrosion (or bleeding/leaching) of other components from above the head.

Response: There are several structures with carbon steel in the leakage path from a postulated CRDM flange leak where the leakage could acquire iron. The insulation support framework, lower shroud, and the vessel head are all carbon steel. Earlier in plant life, the CRDM flange split nut rings were carbon steel. Some of these potential sources could contribute iron if the leakage came from flange leakage. However, in refueling outage 13, the flanges were found to be

free of leakage. Therefore, the upper structures were less compelling candidates to be sources of iron. The conclusion that it came from the head is based on the observation that a large amount of material was removed from the head to form the cavity.

19. Question: Discuss your basis for concluding that the iron present in the radiation monitors came from the vessel head rather than from another source (e.g., boric acid corrosion from other systems, components, or structures).

Response: RCAR Section 3.3.5 (pages 35 and 36) provides the basis for the conclusion that the ferric oxide in the radiation monitor filters was from the CRD nozzle leak.

20. Question: If the root cause is attributed to leakage from a nozzle, discuss the implications to the industry susceptibility ranking. That is, are the results at Davis-Besse consistent with industry trends with respect to susceptibility of nozzles to cracking? If the Davis-Besse results are not consistent with the industry model, discuss whether the degradation of the head may have been accelerated/exacerbated by other factors (e.g., deposits on the head, other contaminants from maintenance/fabrication activities, etc.)? Discuss experimental data supporting your conclusion.

Response: Refer to RCAR Section 3.2.1 (pages 8-15). The susceptibility of the Davis-Besse nozzles to cracking was considered to be relatively high per the MRP ranking model and is consistent with the industry trends recently observed.

21. Question: Boric acid corrosion of the reactor pressure vessel head can occur even when there is leakage from a flange (e.g., Turkey Point). Dry boric acid is also corrosive (although the corrosion rate is low). Discuss how these observations were factored into the root cause. Discuss the atmospheric conditions (temperature, relative humidity) at the location where the degradation was found.

Response: Refer to RCAR Section 3.2.4 (pages 20-26). The RCAR discusses that moisture being supplied from below is probably more conducive to corrosion than dry deposits or deposits wetted from above, especially at high leak rates. As discussed on page 21 of the RCAR, the buildup of boric acid around the nozzles from flange leaks could have possibly contributed to "incubating" the corrosion process. This would involve a local area of higher moisture content. While it can

be assumed that the area above the head and below the insulation is very hot, temperature and humidity information is not available.

22. Question: Discuss your basis for concluding that the crack in nozzle 3 did not go through-wall in the late 1990s (e.g., 1999) and rapid erosion/corrosion of the head occurred. Provide your experimental data supporting your conclusion. Discuss the similarity between the experimental conditions and the condition of the Davis-Besse head (e.g., fabrication dimensions, temperature, air flow, humidity, dry boric acid deposits, boric acid deposits wetted from below and above, etc.).

Response: Refer to RCAR Section 3.2.1 (pages 14 and 15).

23. Question: Discuss your basis for concluding that the corrosion rate is greater in the axial direction than the lateral direction. Discuss the experimental data supporting this conclusion.

Response: Refer to RCAR Section 3.2.4 (pages 20-26). In this case, axial is defined relative to the major dimension of the cavity. The corrosion rates were estimated based on the as-found geometry of the cavity adjacent to nozzle 3 and the results are consistent with the experimental results given in the EPRI Boric Acid Corrosion Guidebook, Revision 1. The rate in the axial direction could be influenced by gravity acting on the wetted area since the axial direction is downhill, or by flow accelerated corrosion since it also lines up reasonably well with the largest nozzle crack.

24. Question: Provide the through-wall profile of the cracks above the weld relative to the interference fit zone. What is the sizing and location of the cracks in nozzle #3 with respect to the interference fit, and with respect to the dimensions of the cavity?

Response: The Ultrasonic Testing (UT) chart shown in RCAR Figure 10 provides the crack length and location. Figure 13 provides the orientation of the cracks relative to the corrosion cavity. The profiles for significant cracks on nozzles 2 and 3 are being developed by Framatome Advanced Nuclear Products for Davis-Besse. These results are planned to be provided to the NRC by May 15, 2002.

25. Question: Since the environmental conditions of the degraded area must have varied as the degradation occurred, provide a degradation mechanism time-line that would describe the conditions at each stage of the degradation from initiation until discovery in March 2002, including the environmental conditions (e.g., oxygen levels and source, boric acid levels and source, moisture levels and source, etc.), the extent of degradation, and the rate of degradation. Provide any physical and experimental information that would support this time-line.

Response: Refer to RCAR Section 3.2.4 (pages 20-26) and Figure 26.

26. Question: Starting in 2000, the deposits on top of the head have been described as lava-like and rock hard. What is the explanation for the change in the character of the deposits on top of the head and what role does this have in describing or explaining the formation of the cavity?

Response: Refer to RCAR Section 3.2.4 (pages 20-26) .

27. Question: When water from the leaking nozzles flashes to steam after having exited from the nozzle, does the process of flashing to steam provide any corrosion potential to the surrounding head material?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

28. Question: When the leaking water flashes to steam, where does the steam go? Does it increase the relative humidity in the area between the RPV head and the insulation, does it saturate the boron deposits, etc.?

Response: Refer to RCAR Section 3.2.4 (pages 20-26).

29. Question: At the 2000 outage, a flange with a high leak rate was repaired. How did this condition contribute to the formation and growth of the cavity, and the appearance of the lava-like or rock hard deposits identified at the 2000 outage?

Response: Some of the leakage from the flange may have migrated to the head surface. However, this is not considered significant, since nozzle leakage would already have been well underway. The primary effect of leaking flanges has been to obscure symptoms of nozzle leakage and to mislead plant staff into believing that CRD nozzles were not leaking. Refer to RCAR Section 3.3.3 (page 29), and Section 3.2.4 (pages 20-26) for additional information.

30. Question: Should the physical evidence not provide definitive support for the root cause, what experimental data will be developed to conclusively demonstrate the root cause for the Davis-Besse degradation?

Response: Physical evidence does support the general cause and timeline (See RCAR Figure 26, page 116) of the crack development, leakage progression, and corrosive attack sufficiently to formulate effective corrective actions to prevent recurrence.

31. Question: How much boric acid on the head would be required to support the degradation identified at Davis-Besse?

Response: Davis-Besse had large accumulations of boric acid (estimated at 900 lbs.) at the beginning of refueling outage 13. The relationship of the amount of pre-existing boric acid buildup to the potential for corrosion damage is not definitively known. Refer to RCAR Section 3.2.4 (pages 20-26).

32. Question: Describe the mechanism for migration of boric acid and corrosion products from the head to the radiation monitors.

Response: See RCAR Section 3.3.5 (pages 35 and 36).

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COMMITMENT LIST

The following list identifies those actions committed to by the Davis-Besse Nuclear Power Station (DBNPS) in this document. Any other actions discussed in the submittal represent intended or planned actions by the DBNPS. They are described only for information and are not regulatory commitments. Please notify the Manager - Regulatory Affairs (419-321-8450) at the DBNPS of any questions regarding this document or associated regulatory commitments.

COMMITMENTS

DUE DATE

Provide profiles of significant cracks on nozzles 2 and 3 (refer to question 24 of Enclosure).

May 15, 2002